Quantifying the Spectral Absorption Coefficients of Phytoplankton and Non-Phytoplankton Components of Seawater from in Situ and Remote-Sensing Measurements

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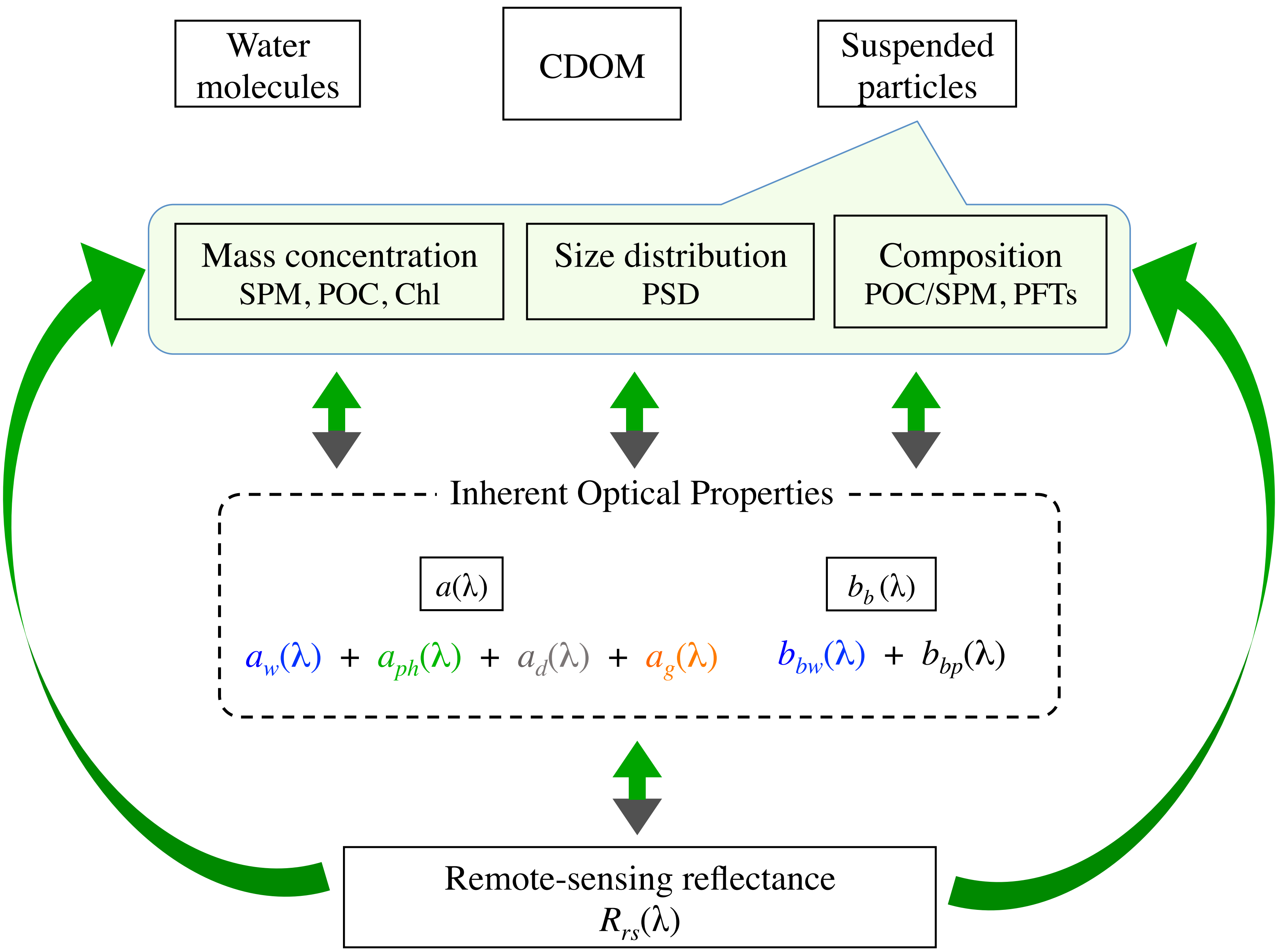
PACE Science Team Meeting
Hyattsville, 14–16 January 2015

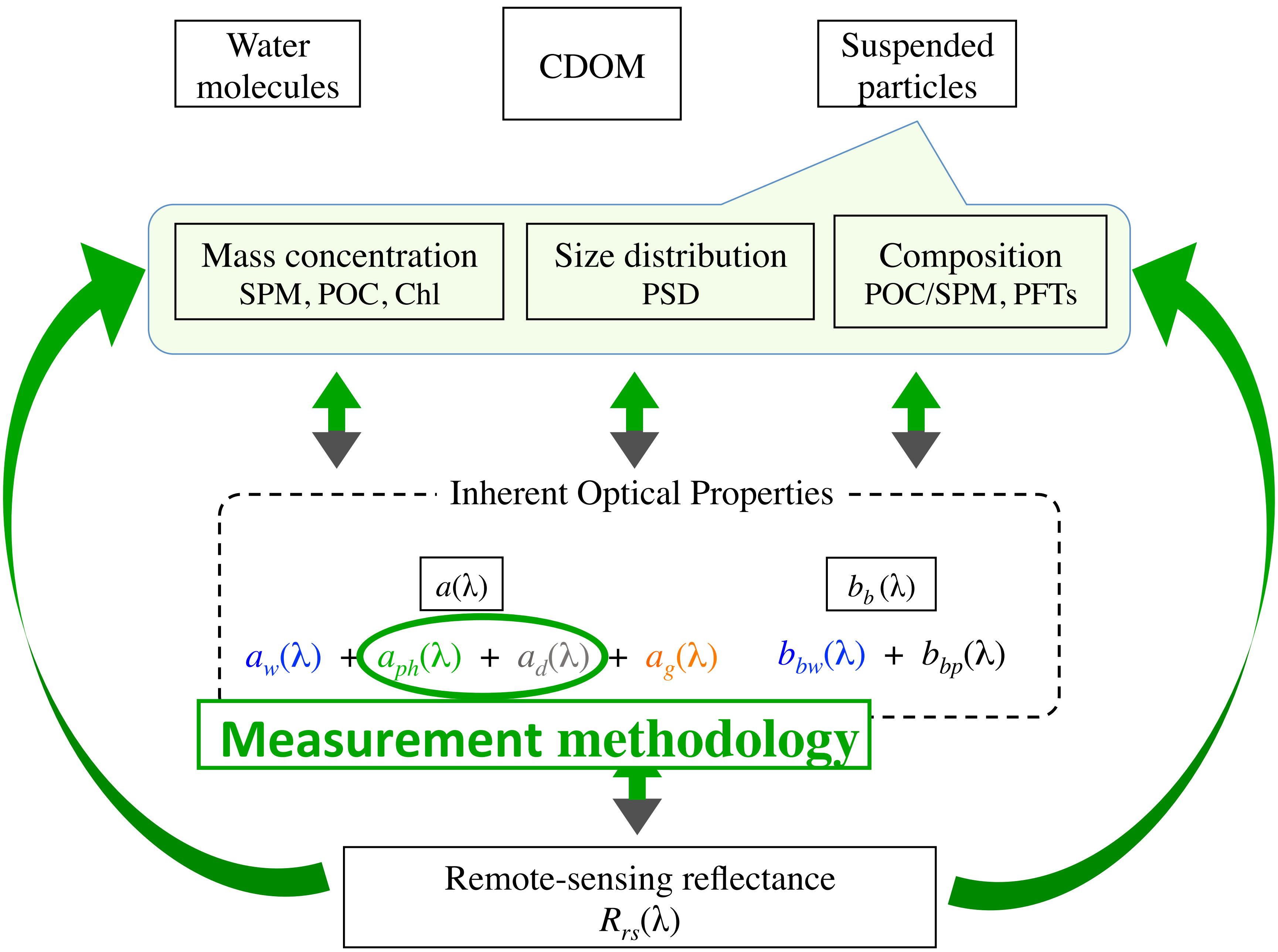
Objectives

- **IOP METHODOLOGY**: Develop consensus recommendations for improved methodology for hyperspectral measurements of particulate absorption coefficient.
  - Develop a protocol with reduced and quantified uncertainties for an improved filter-pad approach with center-mounted samples within an integrating sphere (IS).
  - Quantify uncertainties and develop improved protocols for traditional filter-pad methods: transmittance T and transmittance-reflectance T-R.

- **IOP INVERSION**: Develop a retrieval algorithm for partitioning the total absorption coefficient of seawater into the contributions of phytoplankton, nonalgal particles, and colored dissolved organic matter (CDOM) with a key novel aspect of separating nonalgal particles from CDOM.



Water molecules
CDOM
Suspended particles
Mass concentration
SPM, POC, Chl
Size distribution
PSD
Composition
POC/SPM, PFTs
Inherent Optical Properties
$a(\lambda)$
$b_b(\lambda)$
$a_w(\lambda) + a_{ph}(\lambda) + a_d(\lambda) + a_g(\lambda)$
$b_{bw}(\lambda) + b_{bp}(\lambda)$
Remote-sensing reflectance
$R_{rs}(\lambda)$



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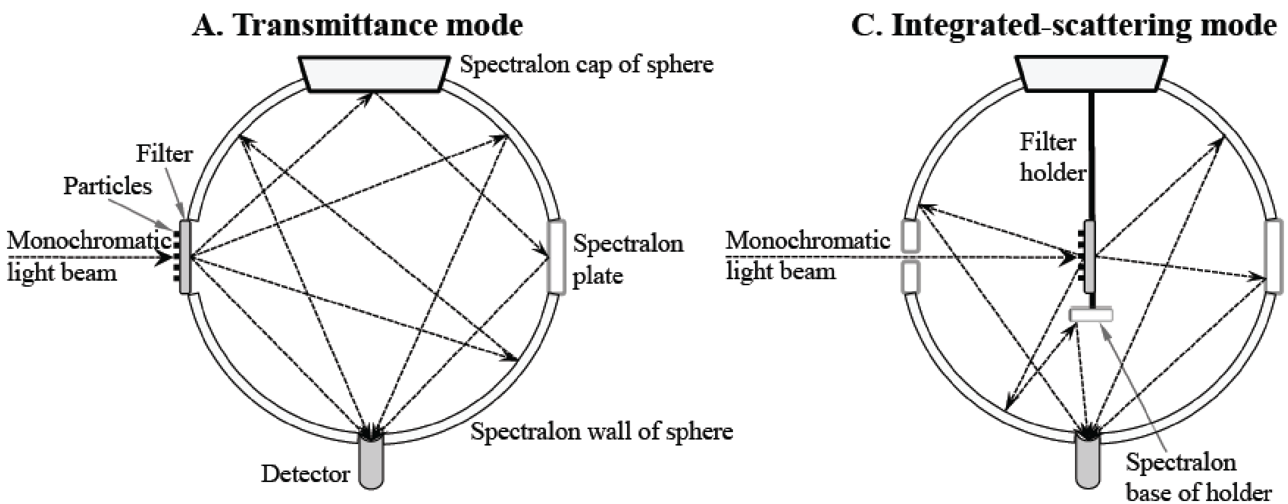
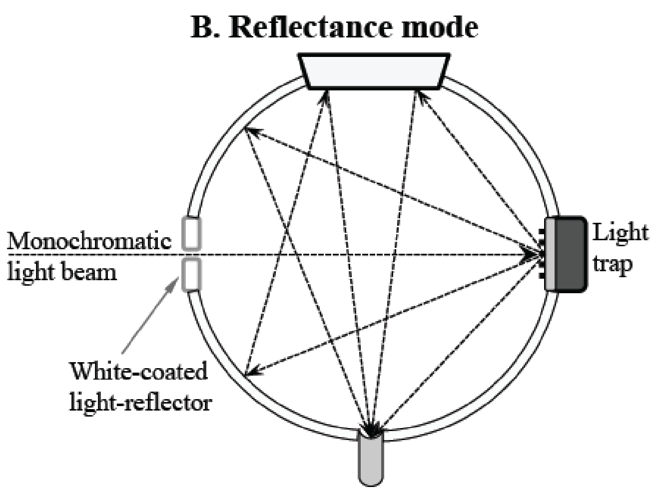
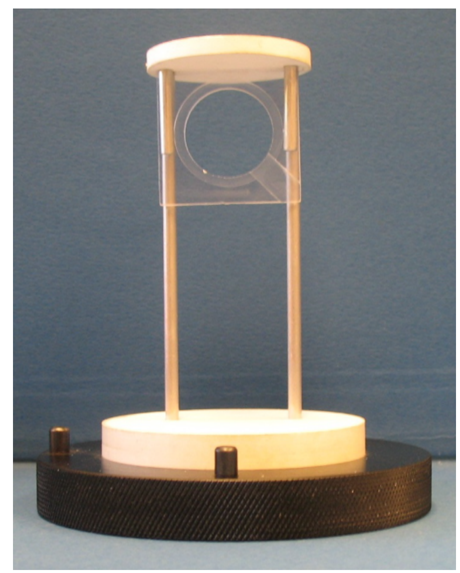
$a_w(\lambda) + a_{ph}(\lambda) + a_d(\lambda) + a_g(\lambda)$
$b_{bw}(\lambda) + b_{bp}(\lambda)$
Measurement methodology
Remote-sensing reflectance
$R_{rs}(\lambda)$

Determinations of pathlength amplification factor (β) for different configurations of filter-pad method

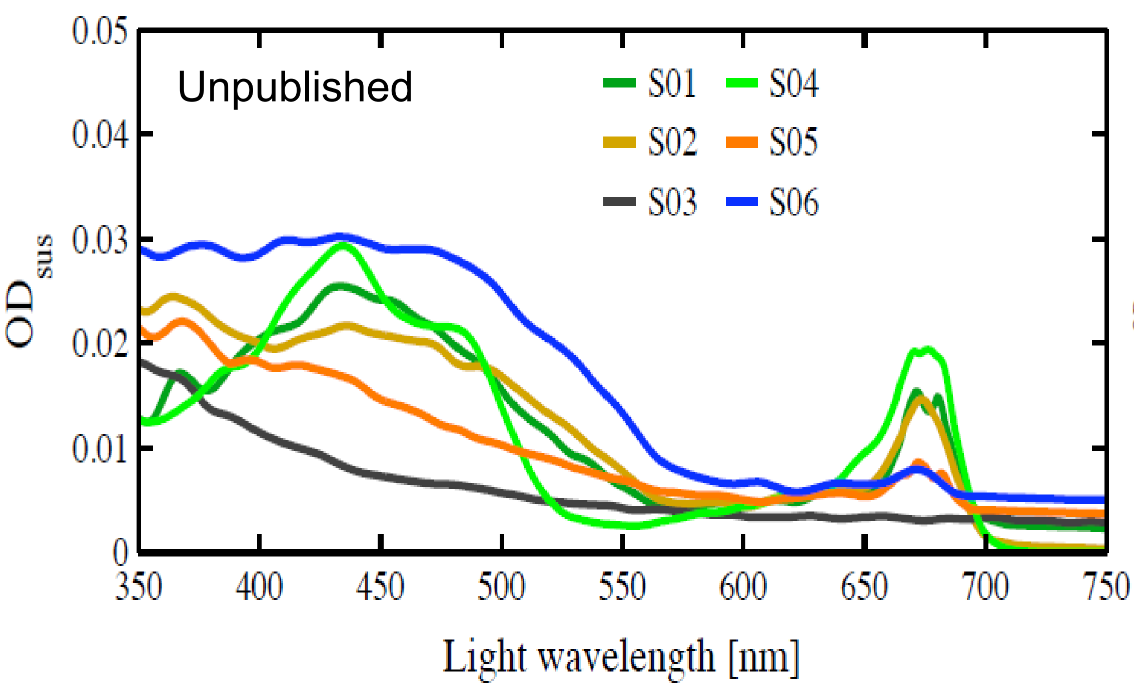


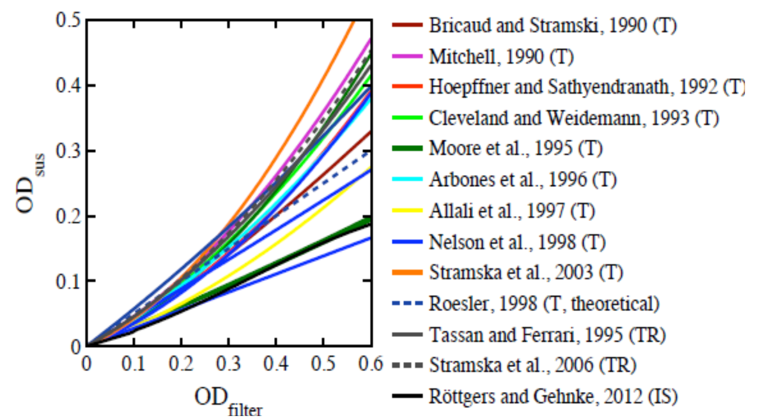


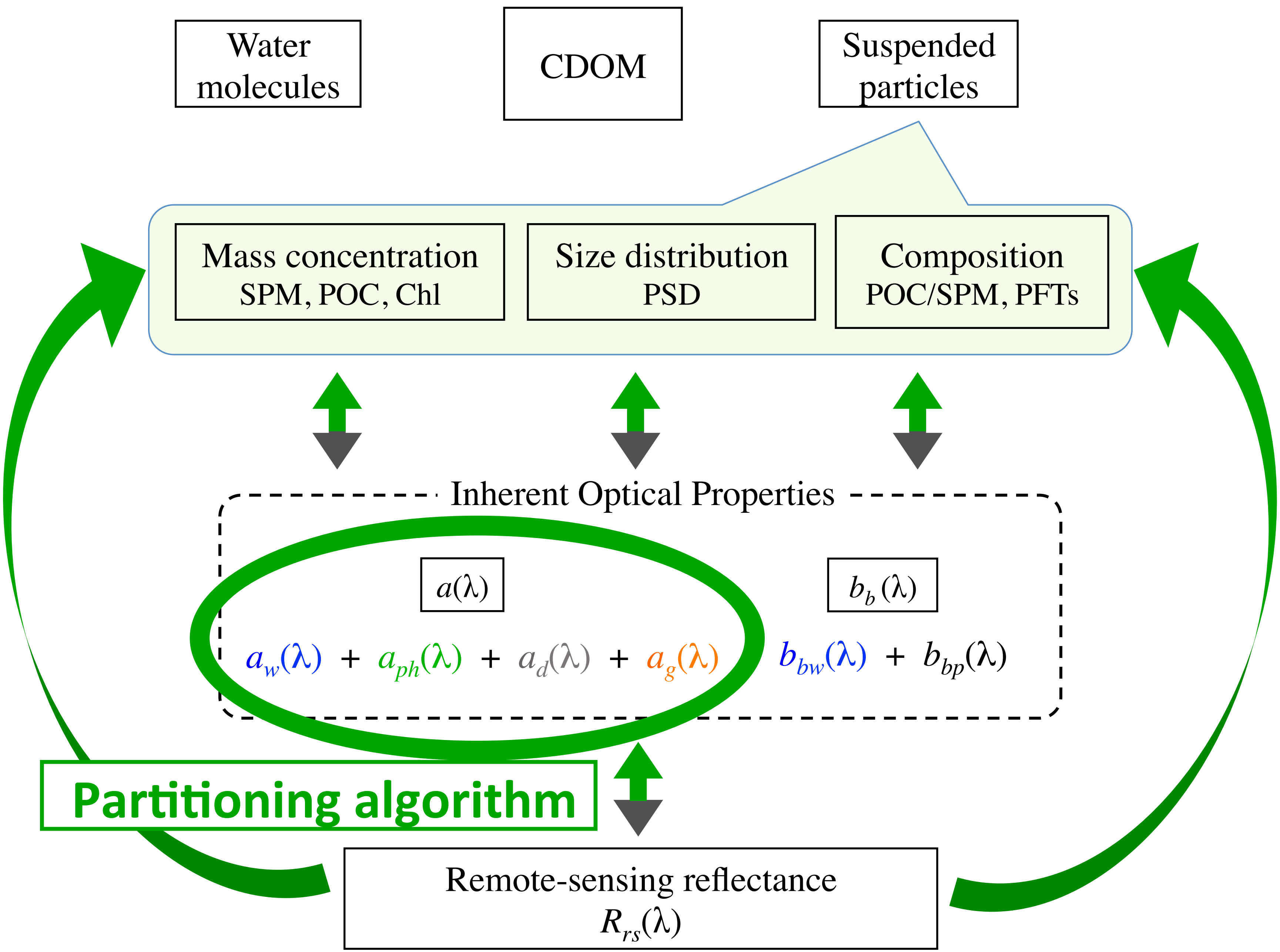


β-experiments

Sample	Filtration volume [mL]						Sample description
	IS				T	R	
S01	5	–	–	–	5	5	Seawater, SIO Pier
S02	3	7	15	23	15	–	Red tide formed by *Lingulodinium polyedrum* SIO Pier
S03	9	19	41	–	41	41	Particle-laden sea ice, Arctic
S04	3	9	15	–	–	–	A mixture of four cultures: *Nannochloropsis, Chlorella vulgaris, Thallasiosira pseudonana,* and *Porphyridium*
S05	5	10	17	25	25	25	Seawater, Imperial Beach Pier (IBP)
S06	9	14.5	–	–	14.5	14.5	Seawater, offshore of San Diego



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Partitioning algorithm
Remote-sensing reflectance
$R_{rs}(\lambda)$

Partitioning of the Absorption Coefficient of Seawater

Pure Seawater

Phytoplankton

Non-algal Particles

CDOM

Colored Dissolved Organic Matter

$$\text{Total } a(\lambda) = a_w(\lambda) + \underbrace{a_{ph}(\lambda) + \underbrace{a_d(\lambda) + a_g(\lambda)}_{a_{dg}(\lambda)}}_{\text{Total non-water } a_{nw}(\lambda)}$$

JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS, VOL. 118, 2155–2174, doi:10.1002/jgrc.20115, 2013

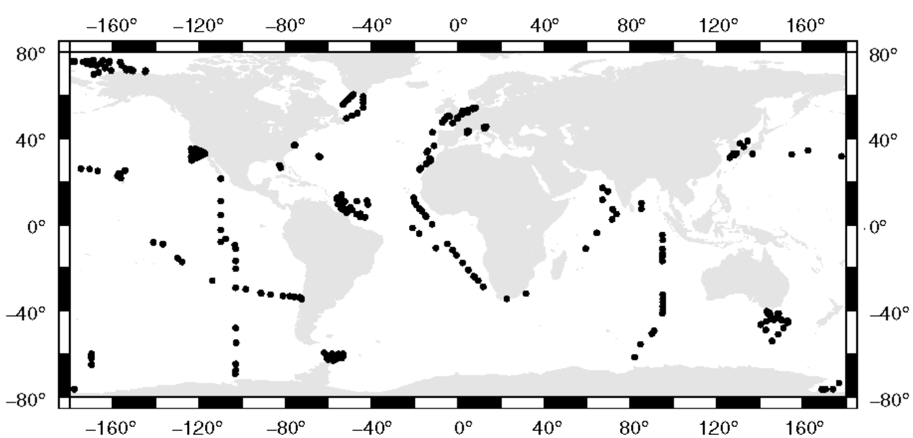
A model based on stacked-constraints approach for partitioning the light absorption coefficient of seawater into phytoplankton and non-phytoplankton components

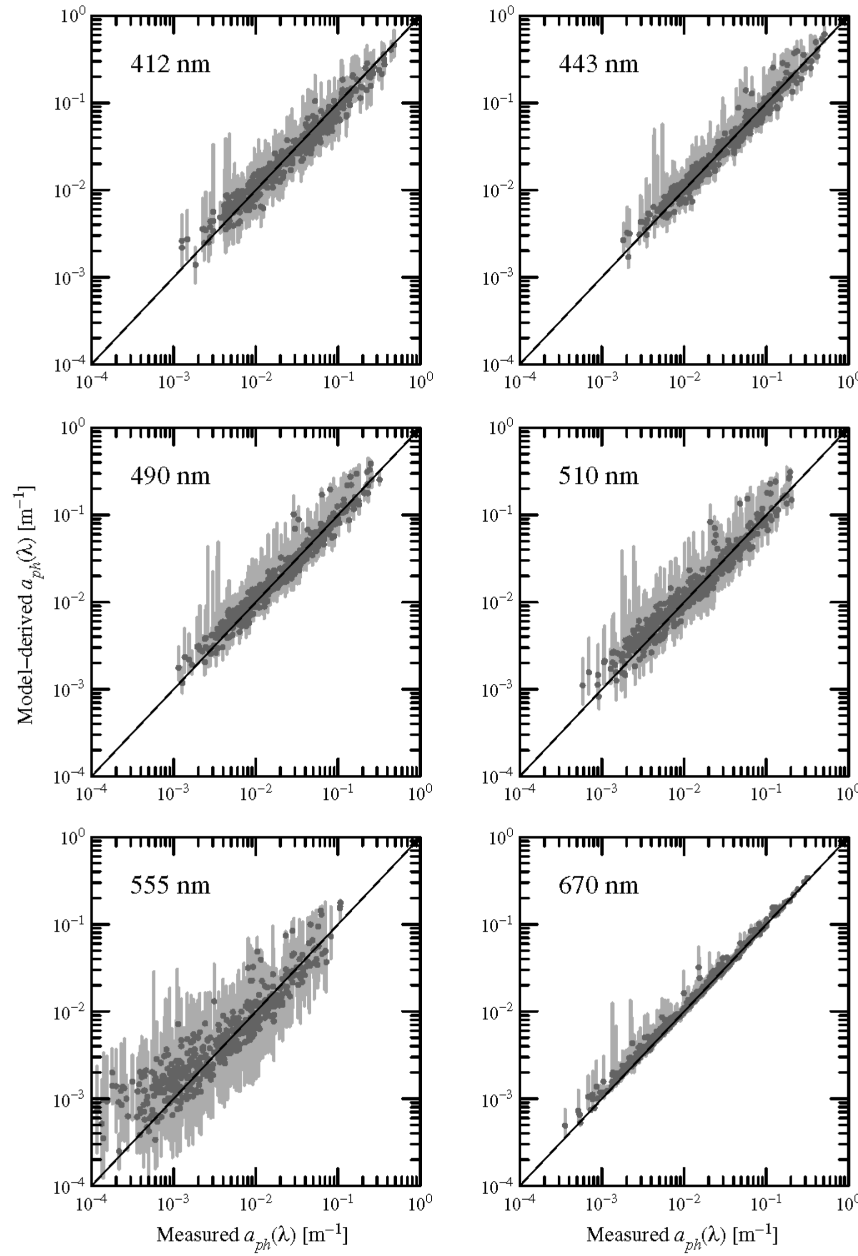
Guangming Zheng[1] and Dariusz Stramski[1]

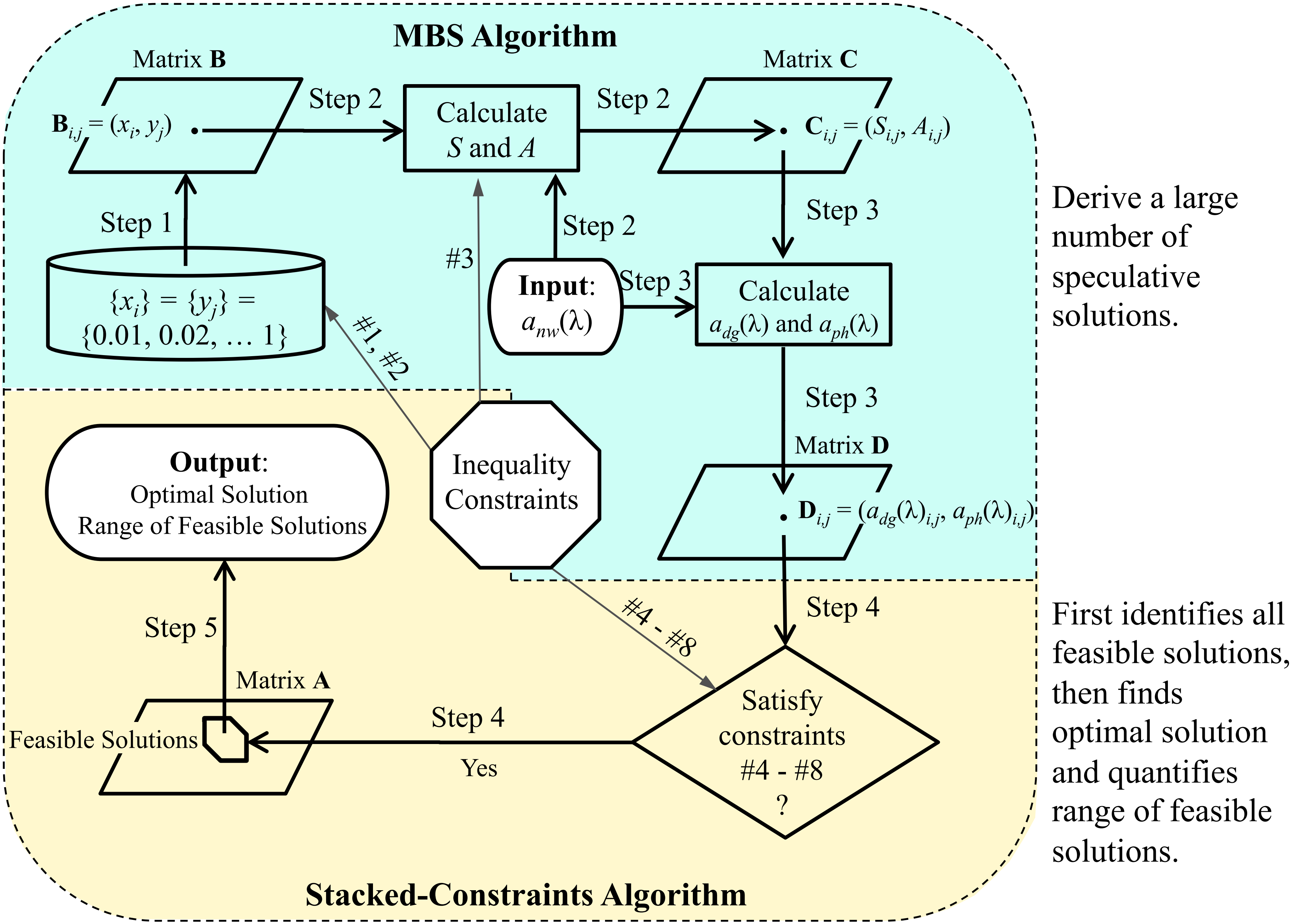
Received 13 September 2012; revised 19 December 2012; accepted 6 February 2013; published 29 April 2013.

[1] Partitioning of the total non-water absorption coefficient of seawater, $a_{nw}(\lambda)$ (i.e., the light absorption coefficient after subtraction of pure water contribution), into phytoplankton, $a_{ph}(\lambda)$, and non-phytoplankton, $a_{dg}(\lambda)$, components is important in the areas of ocean optics, biology, and biogeochemistry. We propose a partitioning model based on stacked-constraints approach, which requires input of $a_{nw}(\lambda)$ at a minimum of six specific light wavelengths. Compared with existing models, our approach requires much less restrictive assumptions about the spectral slope of $a_{dg}(\lambda)$ and the spectral shape of $a_{ph}(\lambda)$. Our model is based on several inequality constraints determined from an extensive, quality-verified set of field data covering oceanic and coastal waters from low to high-latitudes. With these constraints, the model first derives a wide range of speculative solutions for $a_{dg}(\lambda)$ and $a_{ph}(\lambda)$ and then identifies feasible solutions. Final model outputs include the optimal solution and a range of feasible solutions for $a_{dg}(\lambda)$ and $a_{ph}(\lambda)$. The optimal solutions agree well with measurements. For example, the median ratio of the model-derived optimal solutions to measured $a_{dg}(\lambda)$ and $a_{ph}(\lambda)$ at 443 nm is very close to 1, i.e., 1.004 and 0.988, respectively. The median absolute percent difference between the optimal solutions and measured values of $a_{dg}(443)$ and $a_{ph}(443)$ is 6.5% and 12%, respectively. The range of feasible solutions encompasses the measured $a_{dg}(\lambda)$ and $a_{ph}(\lambda)$ with a probability >90% at most wavelengths. Our results support the prospect for the applications of the partitioning model using the input data of $a_{nw}(\lambda)$ collected from various oceanographic and remote-sensing platforms.

Citation: Zheng, G., and D. Stramski (2013), A model based on stacked-constraints approach for partitioning the light absorption coefficient of seawater into phytoplankton and non-phytoplankton components. *J. Geophys. Res. Oceans*, *118*, 2155–2174, doi:10.1002/jgrc.20115.







MBS Algorithm
Matrix B
$\mathbf{B}_{i,j} = (x_i, y_j)$
Step 2
Calculate S and A
Step 2
Matrix C
$\mathbf{C}_{i,j} = (S_{i,j}, A_{i,j})$
Step 1
$\{x_i\} = \{y_j\} = \{0.01, 0.02, \dots 1\}$
#3
Step 2
Input: $a_{nw}(\lambda)$
Step 3
Step 3
Calculate $a_{dg}(\lambda)$ and $a_{ph}(\lambda)$
#1, #2
Step 3
Matrix D
$\mathbf{D}_{i,j} = (a_{dg}(\lambda)_{i,j}, a_{ph}(\lambda)_{i,j})$
Output: Optimal Solution Range of Feasible Solutions
Inequality Constraints
Step 4
#4 - #8
Step 5
Matrix A
Feasible Solutions
Step 4
Yes
Satisfy constraints #4 - #8 ?
Stacked-Constraints Algorithm
Derive a large number of speculative solutions.
First identifies all feasible solutions, then finds optimal solution and quantifies range of feasible solutions.

Activities in 2015

- **IOP METHODOLOGY**:

Stramski, D., R. A. Reynolds, J. Uitz, and G. Zheng, Correction for pathlength amplification in measurements of particulate absorption coefficient in the visible spectral region with a filter-pad method, *Applied Optics.*

- **IOP INVERSION**:

Zheng, G., D. Stramski, P. M. DiGiacomo, A model for partitioning the light absorption coefficient of natural waters into phytoplankton, non-algal particulate, and colored dissolved organic components: A case study for the Chesapeake Bay, *Journal of Geophysical Research – Oceans*.